FIG.1

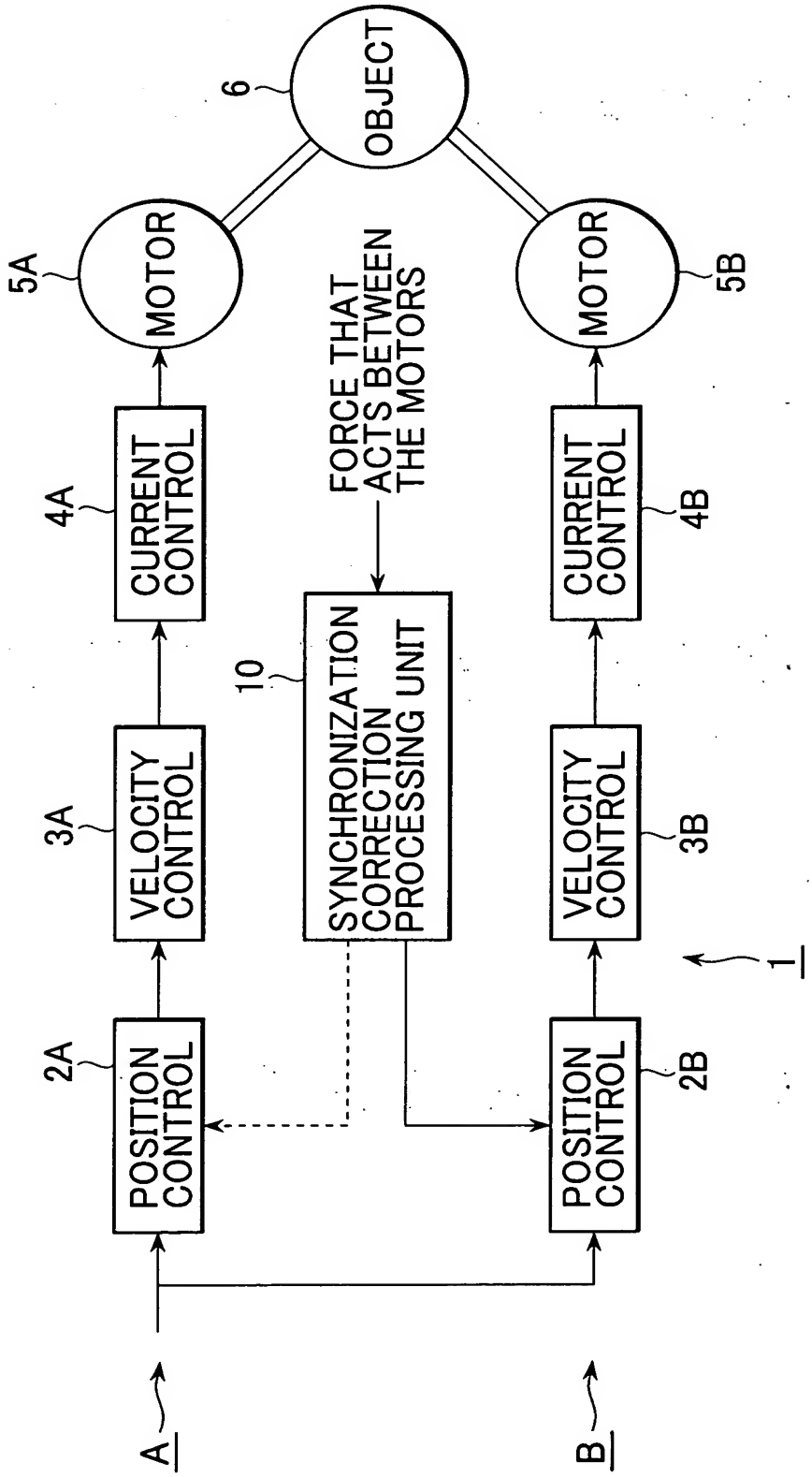

6
OBJECT
5A
MOTOR
5B
MOTOR
FORCE THAT ACTS BETWEEN THE MOTORS
4A
CURRENT CONTROL
4B
CURRENT CONTROL
10
SYNCHRONIZATION CORRECTION PROCESSING UNIT
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
2A
POSITION CONTROL
2B
POSITION CONTROL
1
A
B

FIG.2

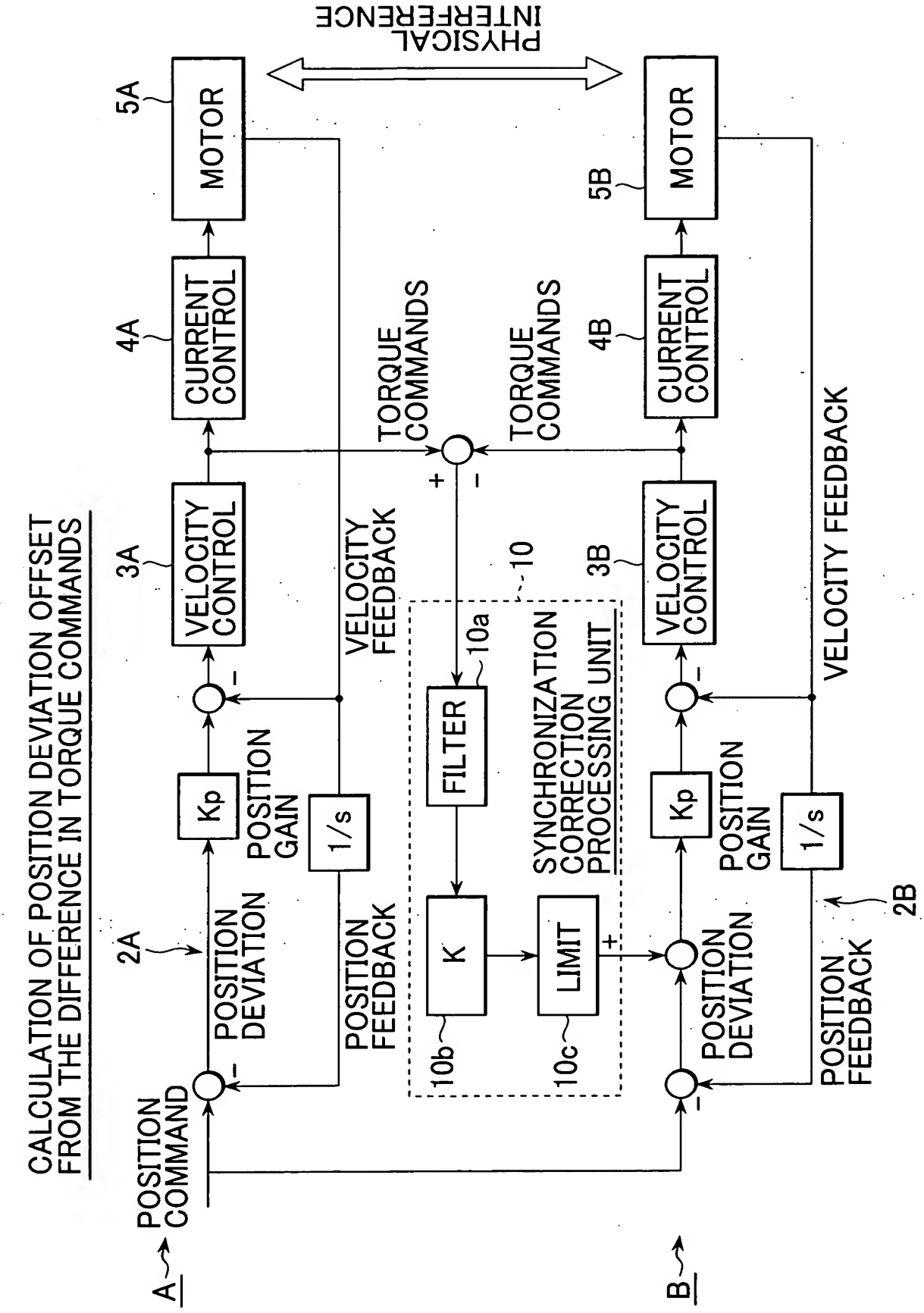

CALCULATION OF POSITION DEVIATION OFFSET FROM THE DIFFERENCE IN TORQUE COMMANDS
PHYSICAL INTERFERENCE
5A
MOTOR
5B
MOTOR
4A
CURRENT CONTROL
4B
CURRENT CONTROL
TORQUE COMMANDS
TORQUE COMMANDS
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
VELOCITY FEEDBACK
10
10a
FILTER
SYNCHRONIZATION CORRECTION PROCESSING UNIT
2A
POSITION DEVIATION
Kp
POSITION GAIN
1/s
POSITION FEEDBACK
K
LIMIT
10b
10c
POSITION COMMAND
A
B
2B

FIG.3

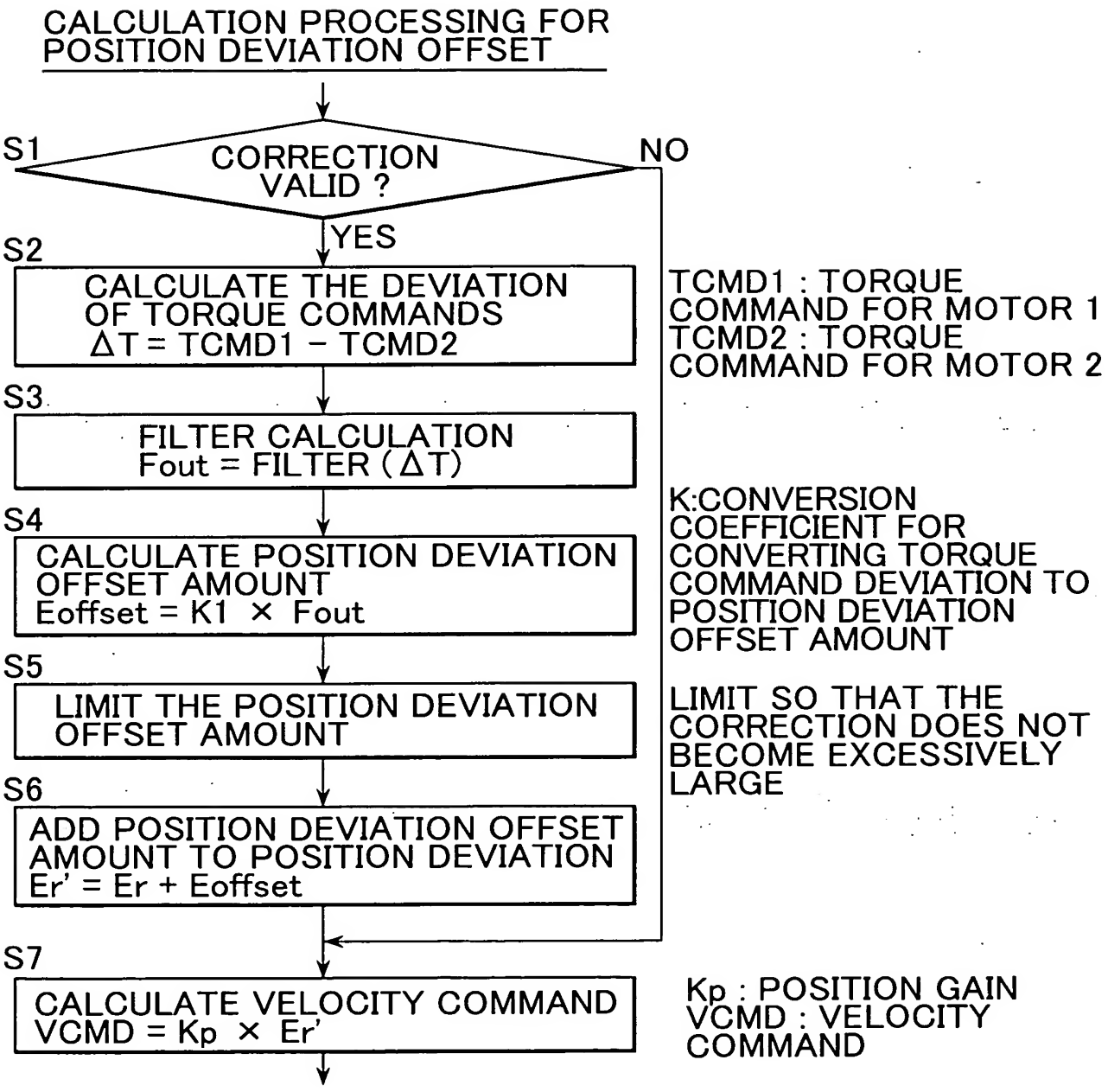

CALCULATION PROCESSING FOR POSITION DEVIATION OFFSET
S1
CORRECTION VALID ?
NO
YES
S2
CALCULATE THE DEVIATION OF TORQUE COMMANDS
ΔT = TCMD1 − TCMD2
TCMD1 : TORQUE COMMAND FOR MOTOR 1
TCMD2 : TORQUE COMMAND FOR MOTOR 2
S3
FILTER CALCULATION
Fout = FILTER (ΔT)
S4
CALCULATE POSITION DEVIATION OFFSET AMOUNT
Eoffset = K1 × Fout
K:CONVERSION COEFFICIENT FOR CONVERTING TORQUE COMMAND DEVIATION TO POSITION DEVIATION OFFSET AMOUNT
S5
LIMIT THE POSITION DEVIATION OFFSET AMOUNT
LIMIT SO THAT THE CORRECTION DOES NOT BECOME EXCESSIVELY LARGE
S6
ADD POSITION DEVIATION OFFSET AMOUNT TO POSITION DEVIATION
Er' = Er + Eoffset
S7
CALCULATE VELOCITY COMMAND
VCMD = Kp × Er'
Kp : POSITION GAIN
VCMD : VELOCITY COMMAND

FIG.4

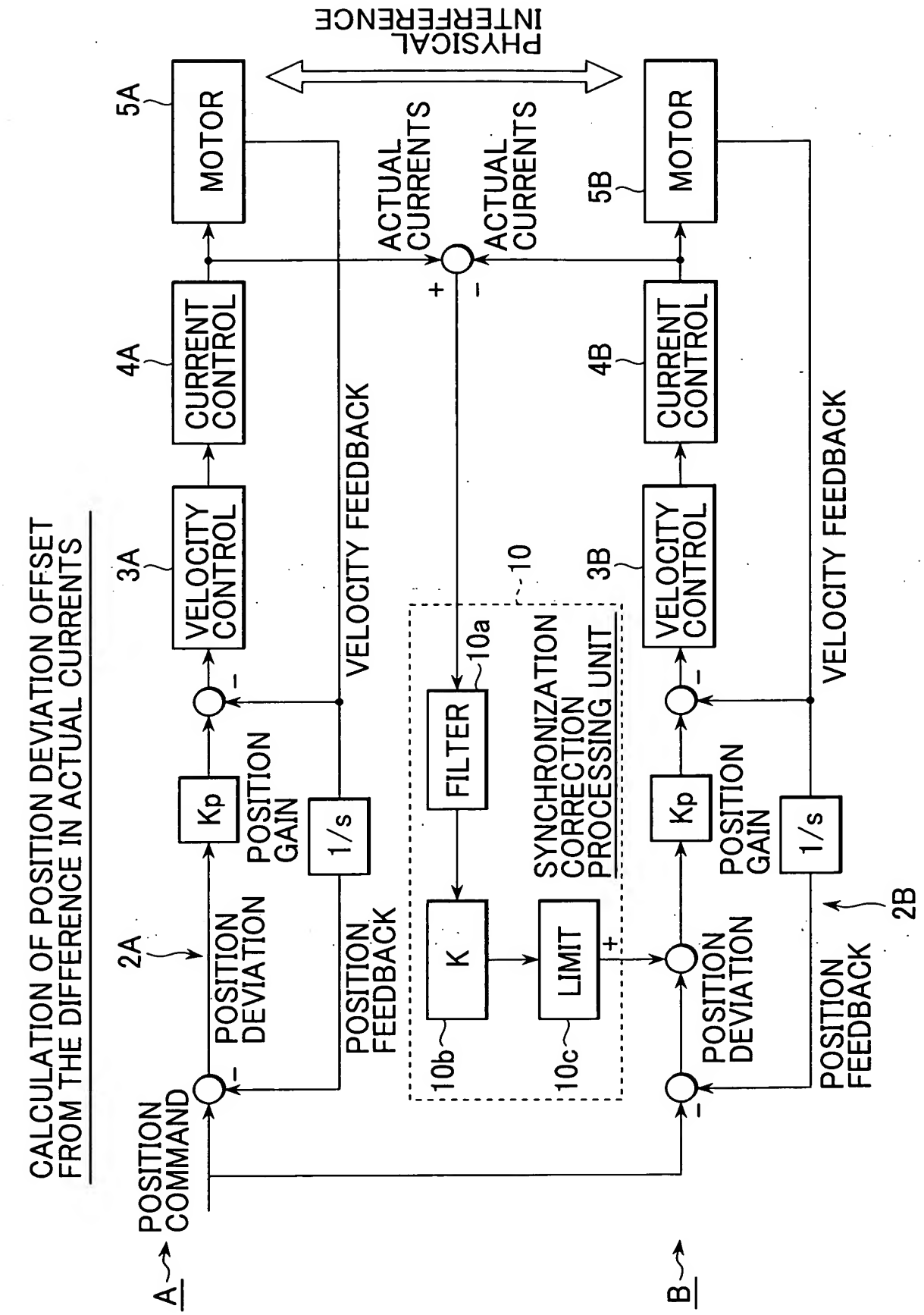

CALCULATION OF POSITION DEVIATION OFFSET FROM THE DIFFERENCE IN ACTUAL CURRENTS
PHYSICAL INTERFERENCE
5A
MOTOR
5B
MOTOR
ACTUAL CURRENTS
ACTUAL CURRENTS
4A
CURRENT CONTROL
4B
CURRENT CONTROL
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
VELOCITY FEEDBACK
10
10a
FILTER
SYNCHRONIZATION CORRECTION PROCESSING UNIT
Kp
POSITION GAIN
Kp
POSITION GAIN
1/s
1/s
2A
POSITION DEVIATION
POSITION FEEDBACK
K
LIMIT
10b
10c
POSITION DEVIATION
POSITION FEEDBACK
2B
POSITION COMMAND
A
B

FIG.5

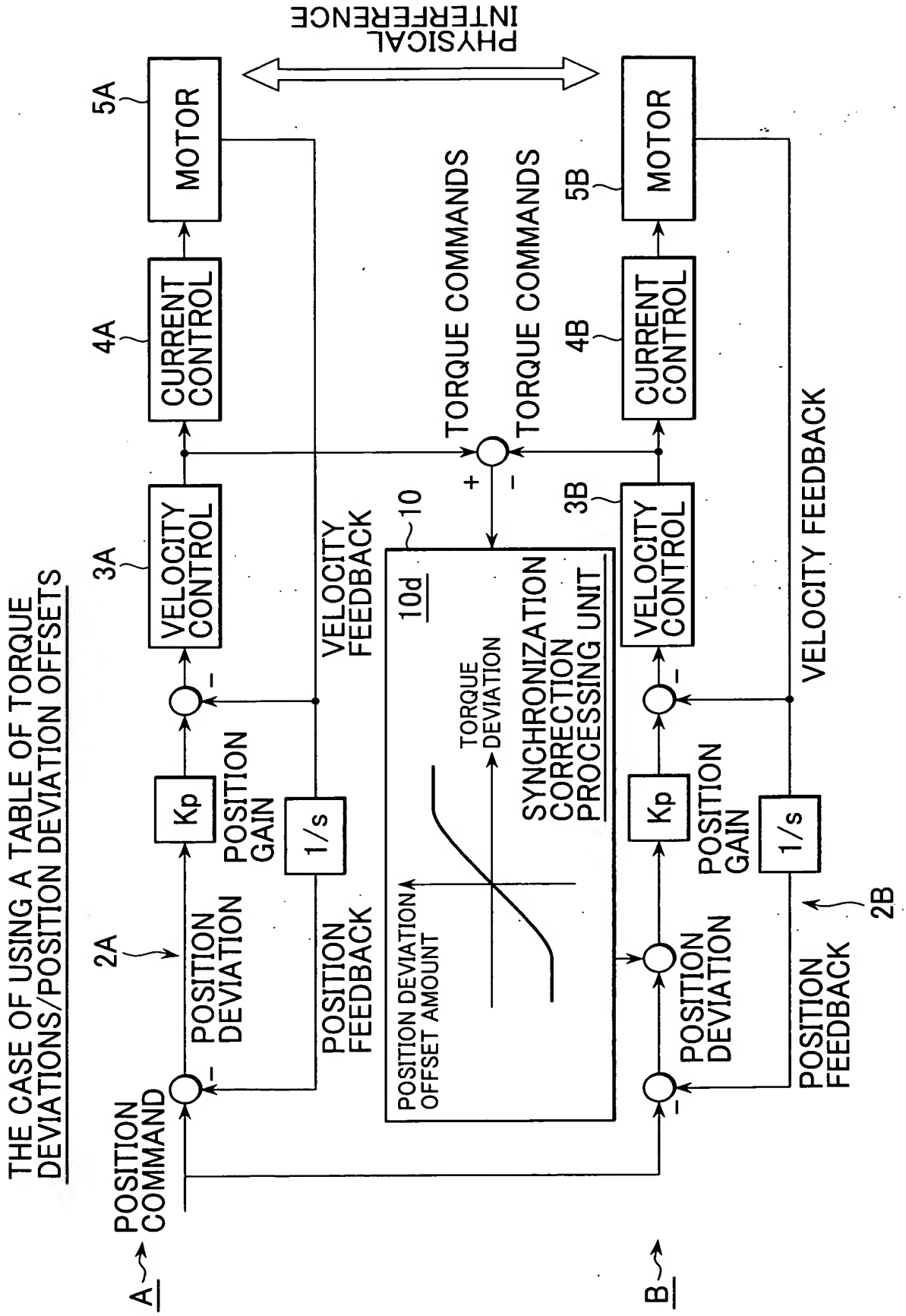

THE CASE OF USING A TABLE OF TORQUE DEVIATIONS/POSITION DEVIATION OFFSETS
PHYSICAL INTERFERENCE
5A
MOTOR
5B
MOTOR
4A
CURRENT CONTROL
4B
CURRENT CONTROL
TORQUE COMMANDS
TORQUE COMMANDS
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
VELOCITY FEEDBACK
10
10d
SYNCHRONIZATION CORRECTION PROCESSING UNIT
TORQUE DEVIATION
POSITION DEVIATION OFFSET AMOUNT
2A
2B
POSITION COMMAND
POSITION DEVIATION
POSITION DEVIATION
POSITION FEEDBACK
POSITION FEEDBACK
Kp
Kp
POSITION GAIN
POSITION GAIN
1/s
1/s
A
B

FIG.6

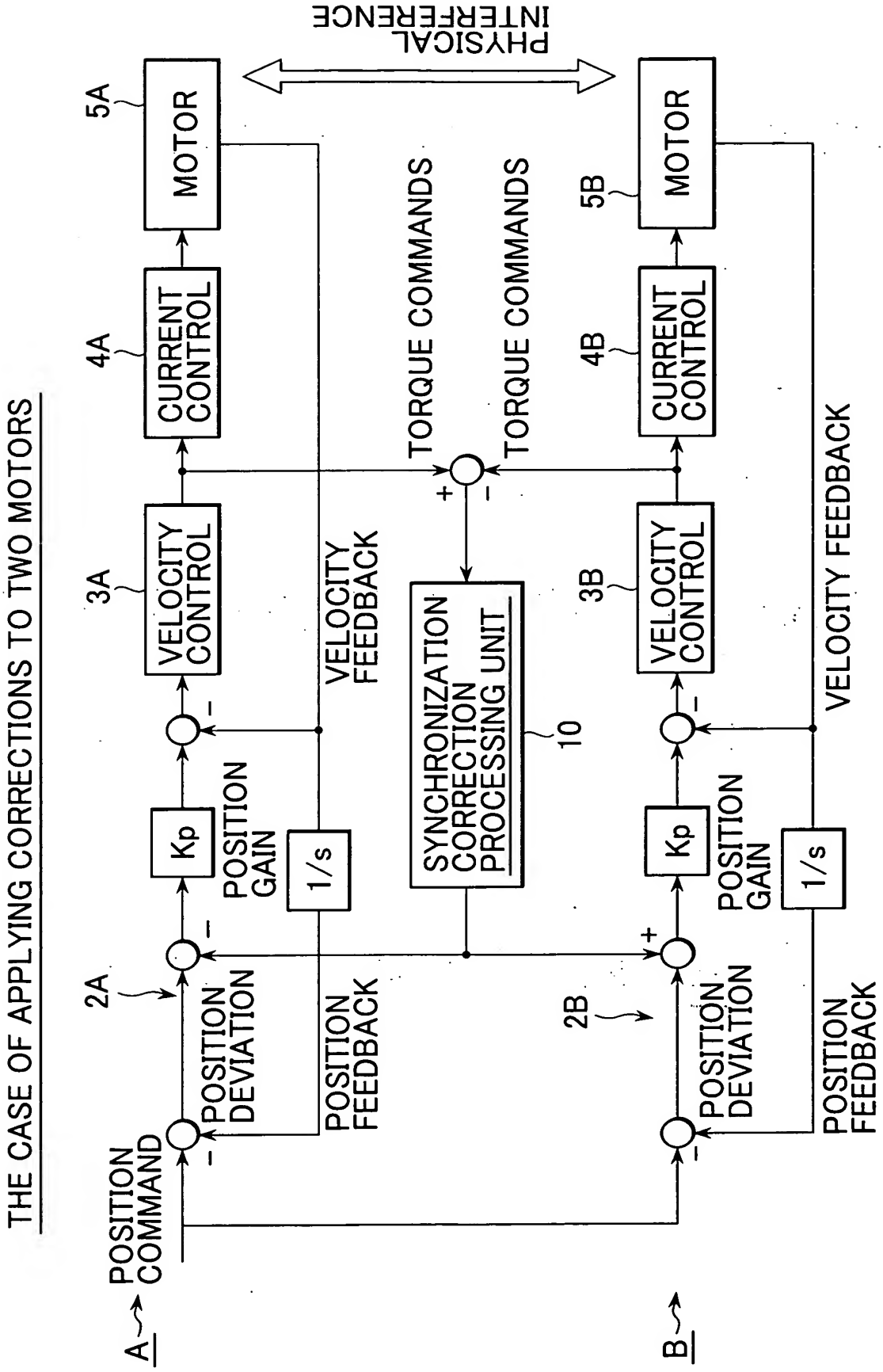

THE CASE OF APPLYING CORRECTIONS TO TWO MOTORS
A
B
POSITION COMMAND
2A
2B
POSITION DEVIATION
POSITION FEEDBACK
Kp
POSITION GAIN
1/s
3A
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
4A
4B
CURRENT CONTROL
TORQUE COMMANDS
SYNCHRONIZATION CORRECTION PROCESSING UNIT
10
5A
5B
MOTOR
PHYSICAL INTERFERENCE

FIG.7

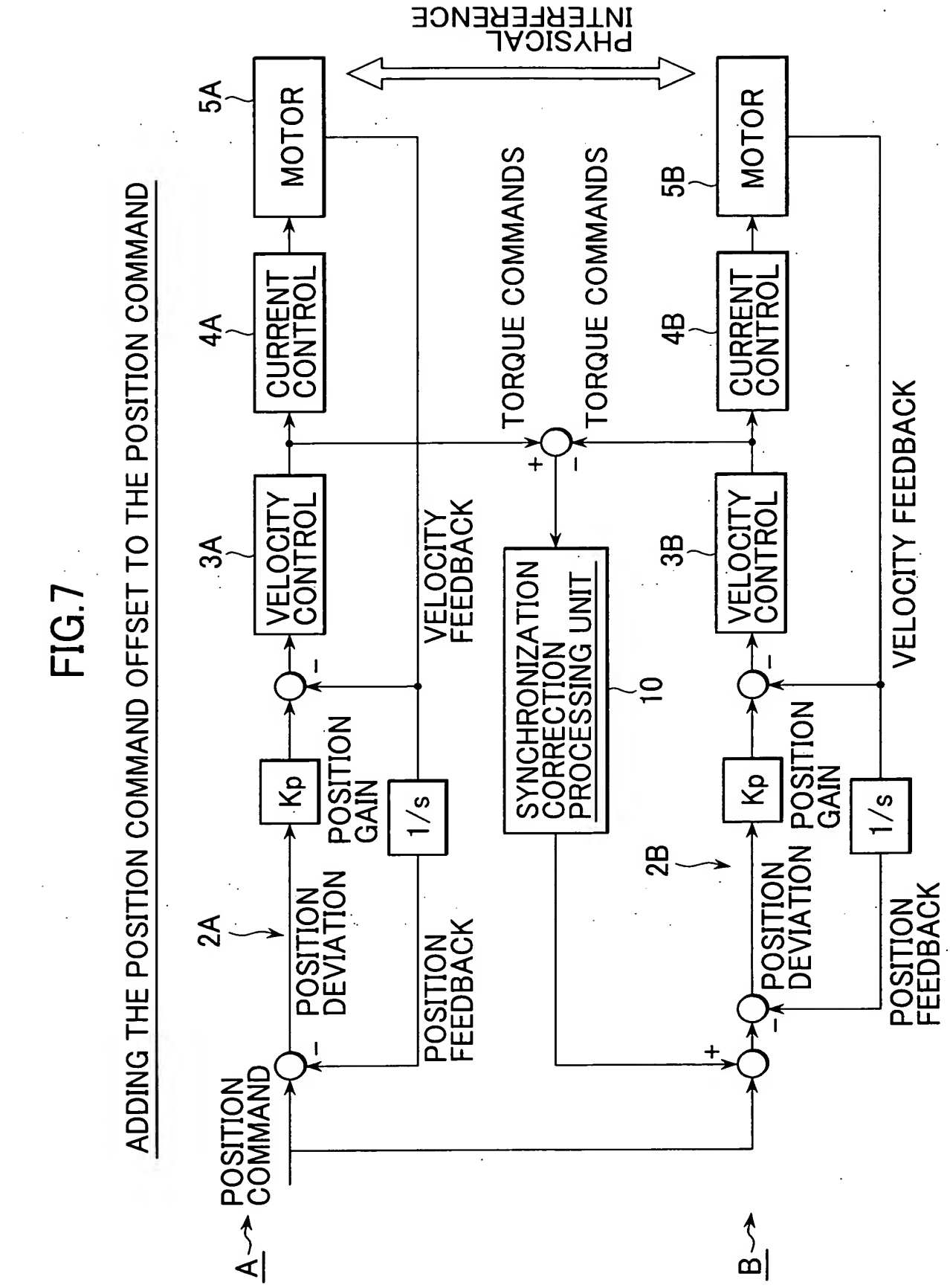

ADDING THE POSITION COMMAND OFFSET TO THE POSITION COMMAND
PHYSICAL INTERFERENCE
5A
MOTOR
5B
MOTOR
4A
CURRENT CONTROL
4B
CURRENT CONTROL
TORQUE COMMANDS
TORQUE COMMANDS
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
VELOCITY FEEDBACK
SYNCHRONIZATION CORRECTION PROCESSING UNIT
10
2A
2B
POSITION DEVIATION
POSITION DEVIATION
Kp
POSITION GAIN
Kp
POSITION GAIN
1/s
1/s
POSITION FEEDBACK
POSITION FEEDBACK
POSITION COMMAND
A
B

FIG.8

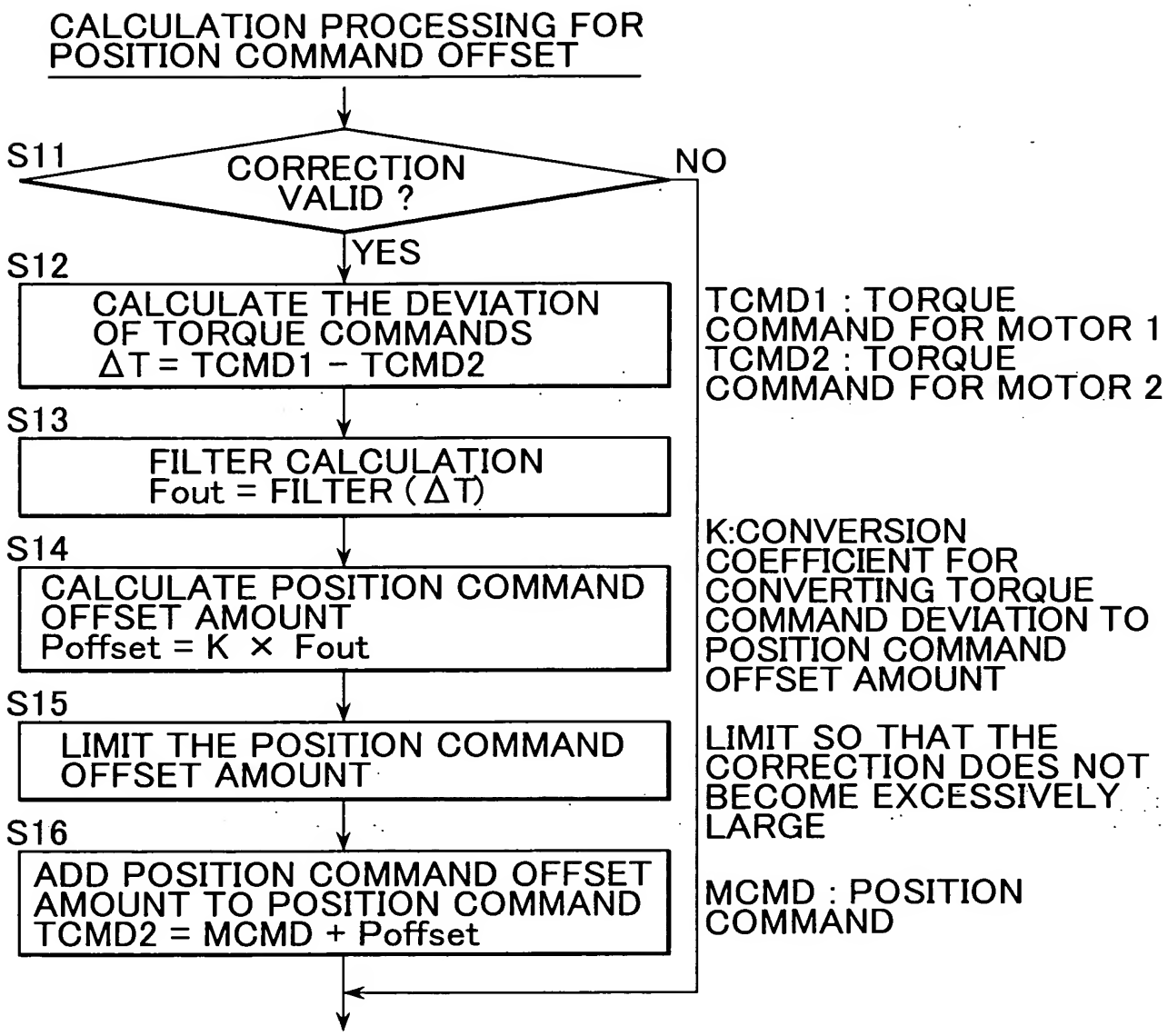

CALCULATION PROCESSING FOR POSITION COMMAND OFFSET
S11
CORRECTION VALID ?
NO
YES
S12
CALCULATE THE DEVIATION OF TORQUE COMMANDS
ΔT = TCMD1 − TCMD2
TCMD1 : TORQUE COMMAND FOR MOTOR 1
TCMD2 : TORQUE COMMAND FOR MOTOR 2
S13
FILTER CALCULATION
Fout = FILTER (ΔT)
S14
CALCULATE POSITION COMMAND OFFSET AMOUNT
Poffset = K × Fout
K:CONVERSION COEFFICIENT FOR CONVERTING TORQUE COMMAND DEVIATION TO POSITION COMMAND OFFSET AMOUNT
S15
LIMIT THE POSITION COMMAND OFFSET AMOUNT
LIMIT SO THAT THE CORRECTION DOES NOT BECOME EXCESSIVELY LARGE
S16
ADD POSITION COMMAND OFFSET AMOUNT TO POSITION COMMAND
TCMD2 = MCMD + Poffset
MCMD : POSITION COMMAND

FIG.9

CALCULATION OF THE POSITION COMMAND OFFSET FROM THE DIFFERENCE IN ACTUAL CURRENTS

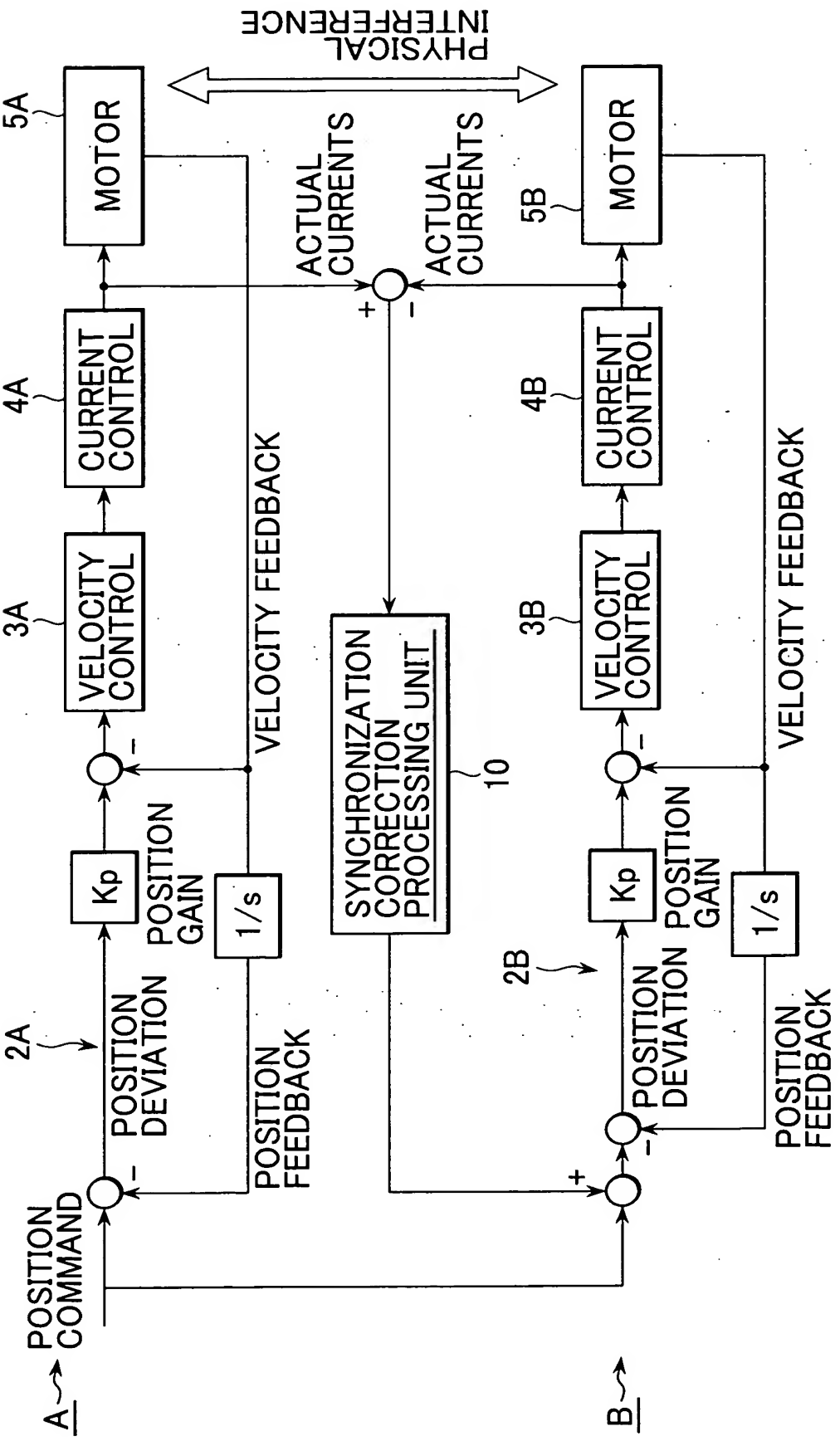


FIG.10

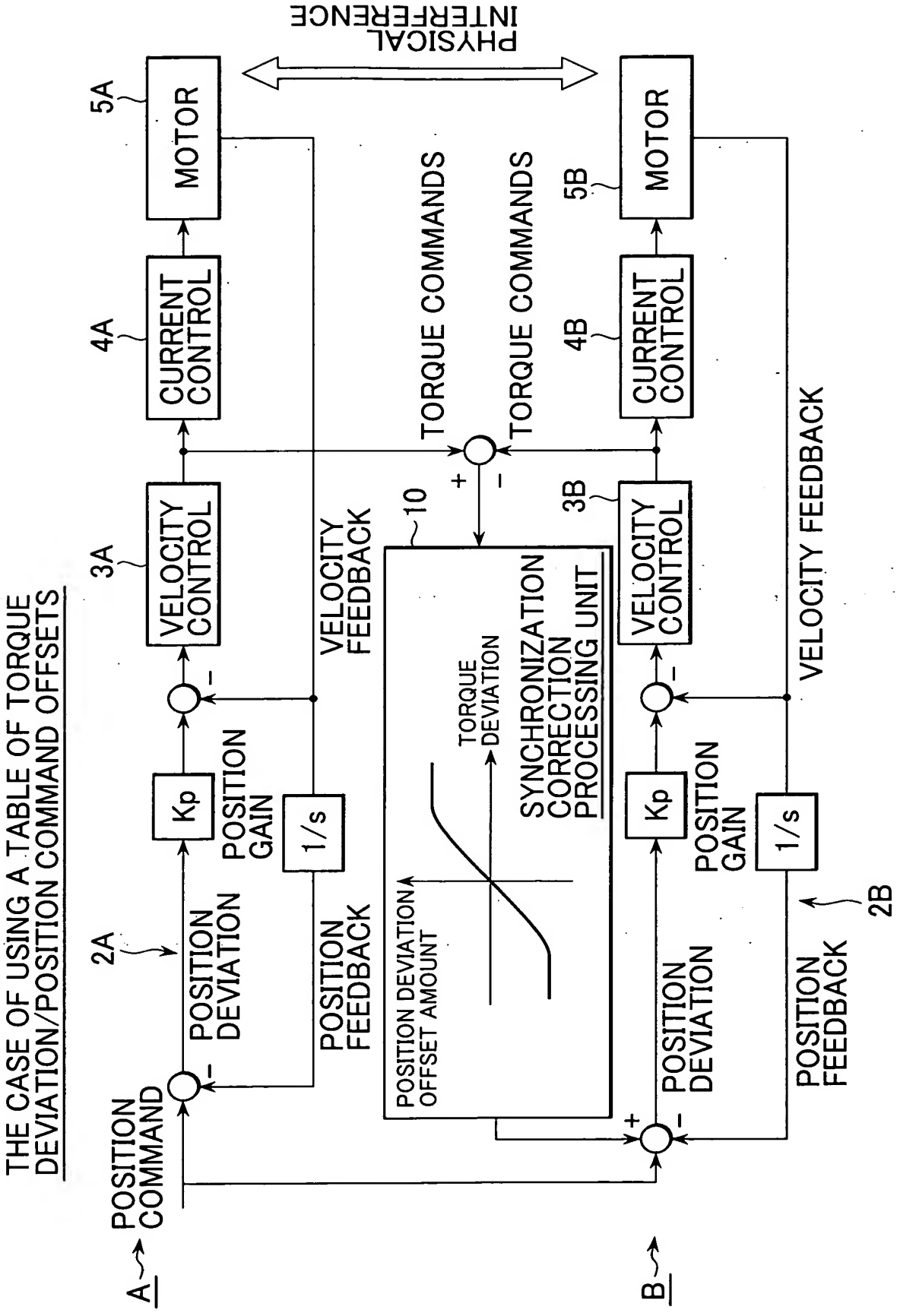

THE CASE OF USING A TABLE OF TORQUE DEVIATION/POSITION COMMAND OFFSETS
PHYSICAL INTERFERENCE
5A
MOTOR
5B
MOTOR
4A
CURRENT CONTROL
4B
CURRENT CONTROL
TORQUE COMMANDS
TORQUE COMMANDS
3A
VELOCITY CONTROL
3B
VELOCITY CONTROL
10
VELOCITY FEEDBACK
VELOCITY FEEDBACK
SYNCHRONIZATION CORRECTION PROCESSING UNIT
TORQUE DEVIATION
POSITION DEVIATION OFFSET AMOUNT
2A
POSITION COMMAND
POSITION DEVIATION
POSITION FEEDBACK
Kp
POSITION GAIN
1/s
Kp
POSITION GAIN
1/s
POSITION DEVIATION
POSITION FEEDBACK
2B
A
B

FIG.11

THE CASE OF APPLYING CORRECTIONS TO TWO MOTORS

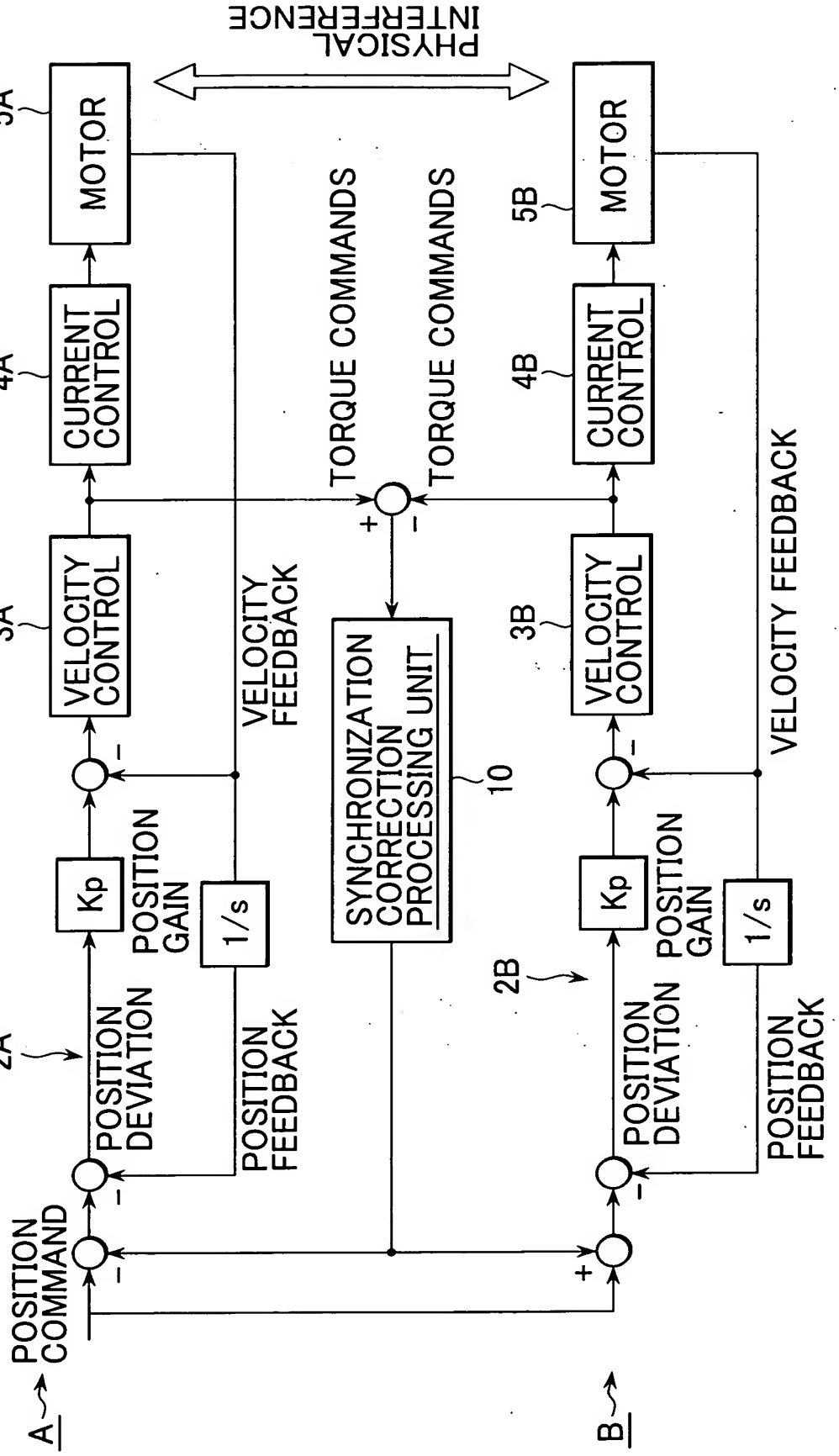


FIG.12

CORRECTING THE POSITION OF ONE MOTOR FROM THE DIFFERENCE IN TORQUE COMMANDS

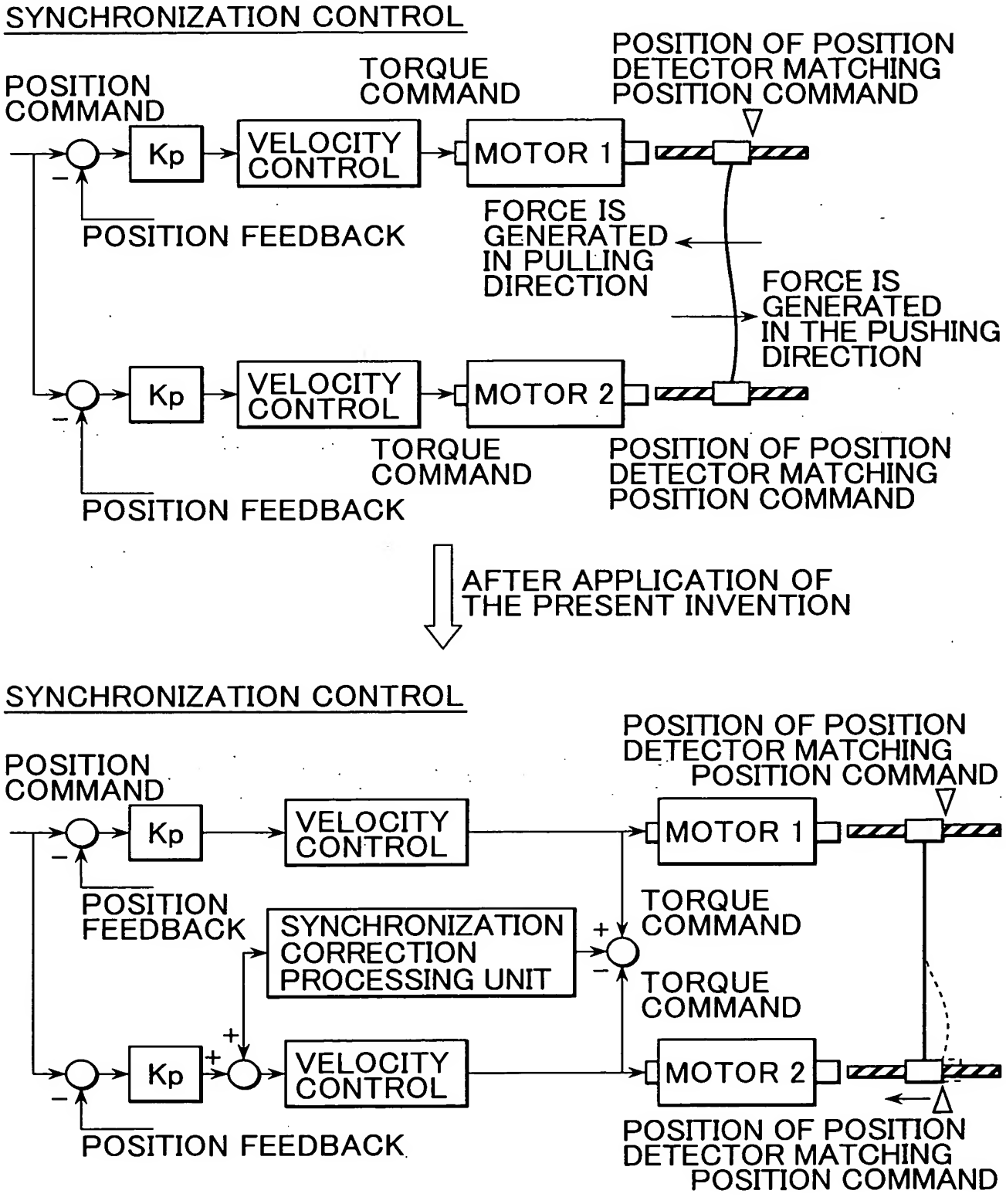


FIG.13A

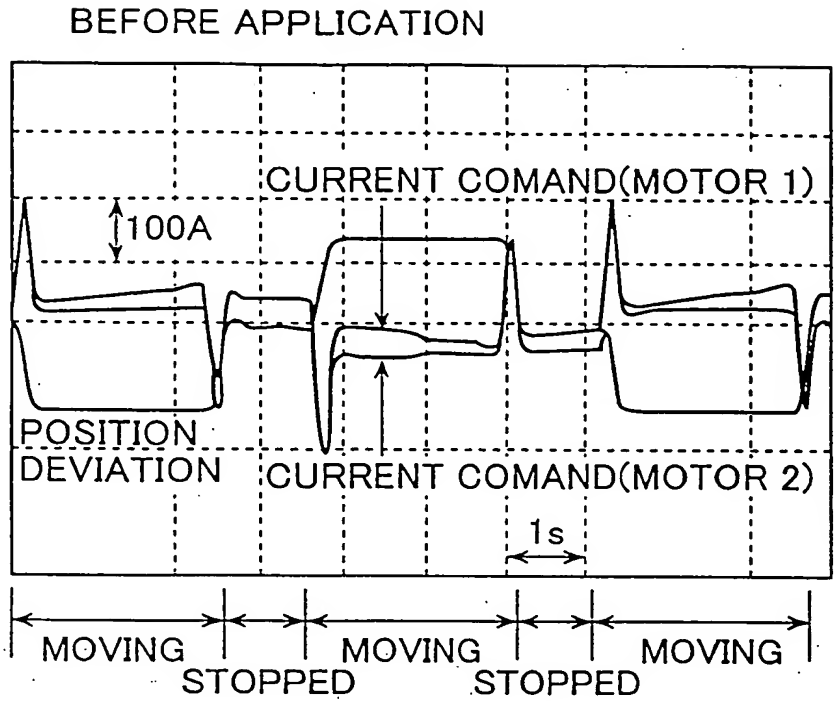


FIG.13B

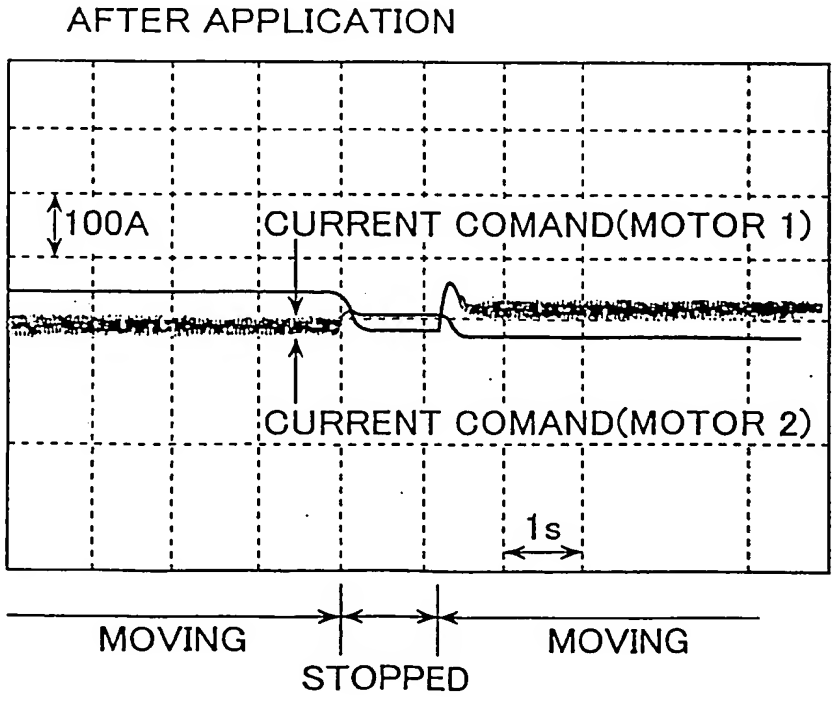


FIG.14A

BEFORE APPLICATION

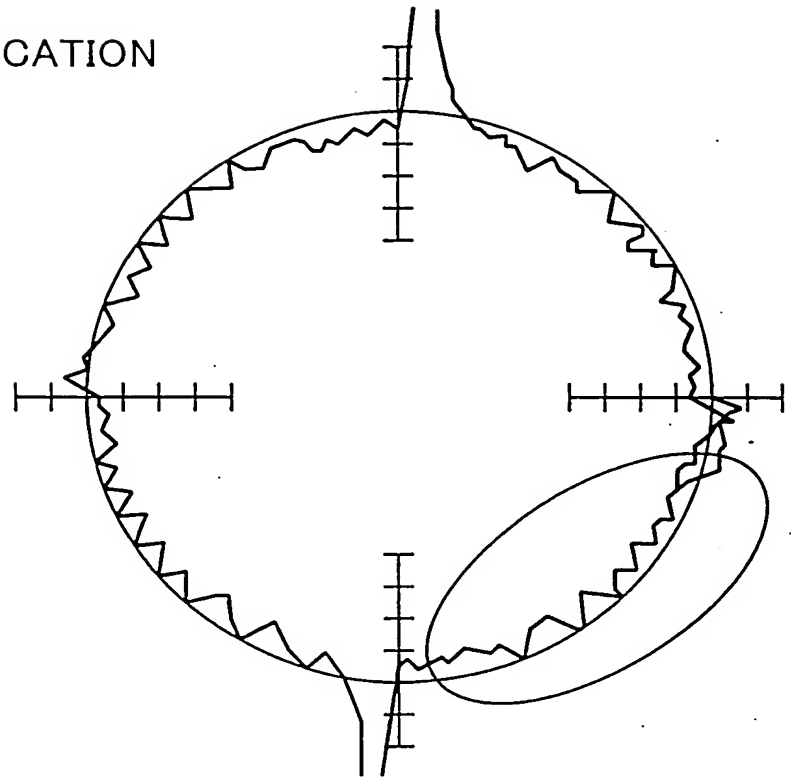


FIG.14B

AFTER APPLICATION

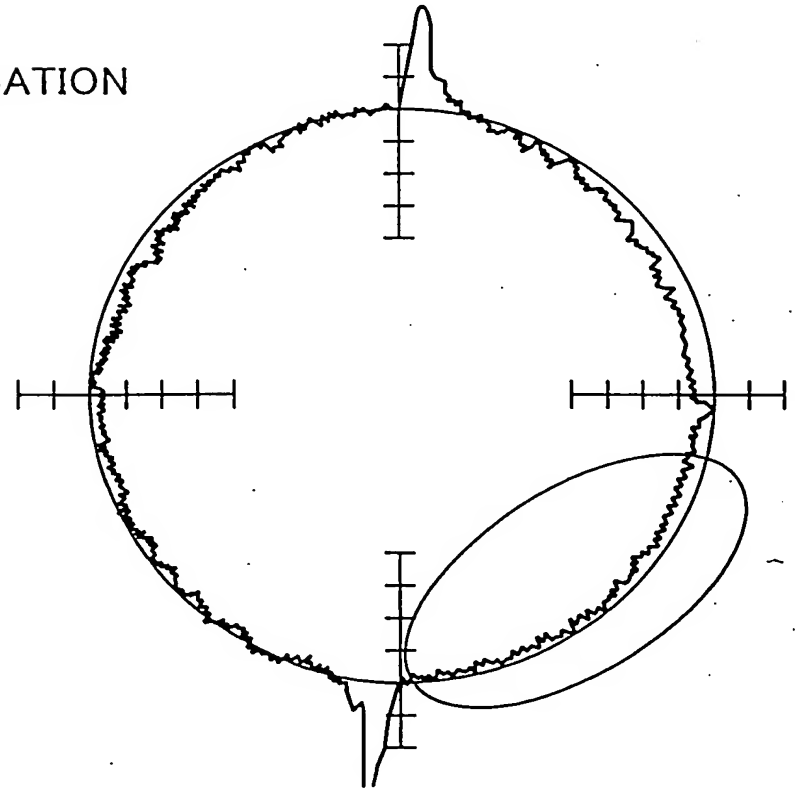


FIG.15

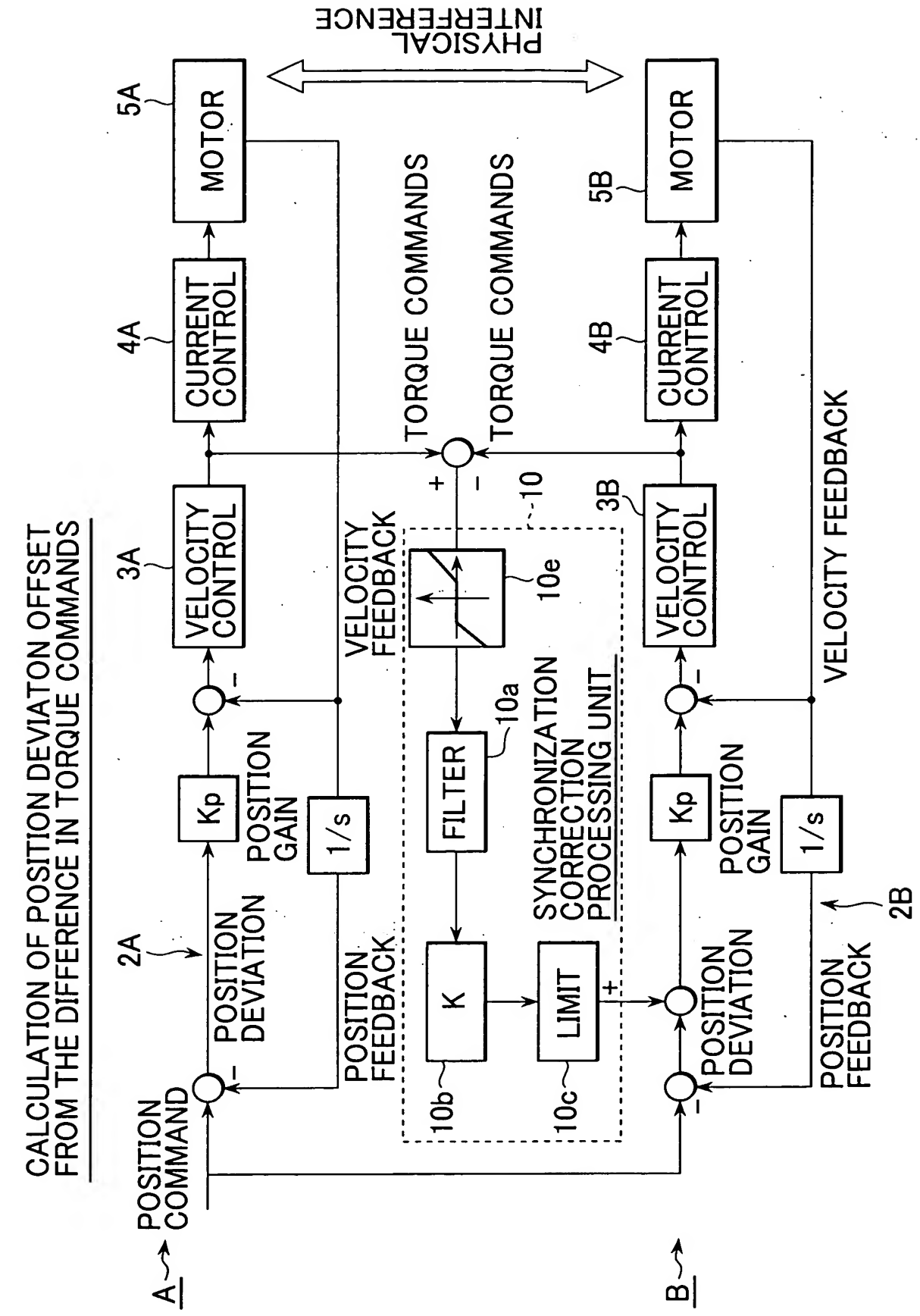

CALCULATION OF POSITION DEVIATON OFFSET FROM THE DIFFERENCE IN TORQUE COMMANDS
PHYSICAL INTERFERENCE
5A
MOTOR
4A
CURRENT CONTROL
3A
VELOCITY CONTROL
TORQUE COMMANDS
TORQUE COMMANDS
5B
MOTOR
4B
CURRENT CONTROL
3B
VELOCITY CONTROL
VELOCITY FEEDBACK
10
10e
10a
FILTER
SYNCHRONIZATION CORRECTION PROCESSING UNIT
10b
K
10c
LIMIT
2A
POSITION COMMAND
POSITION DEVIATION
Kp
POSITION GAIN
1/s
POSITION FEEDBACK
A
B
2B

FIG.16

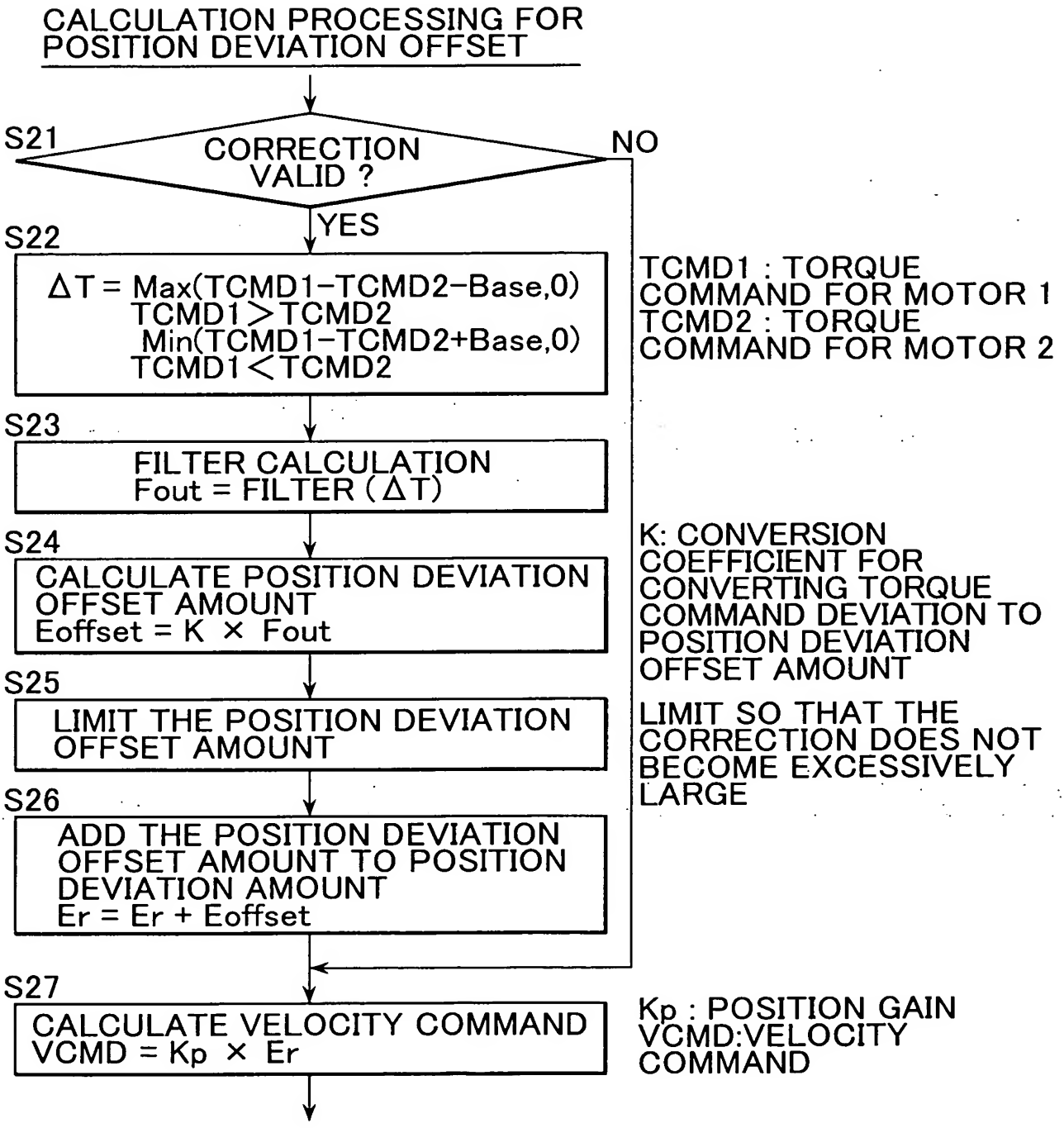

CALCULATION PROCESSING FOR POSITION DEVIATION OFFSET
S21
CORRECTION VALID ?
NO
YES
S22
ΔT = Max(TCMD1−TCMD2−Base,0) TCMD1＞TCMD2
Min(TCMD1−TCMD2+Base,0) TCMD1＜TCMD2
TCMD1 : TORQUE COMMAND FOR MOTOR 1
TCMD2 : TORQUE COMMAND FOR MOTOR 2
S23
FILTER CALCULATION
Fout = FILTER (ΔT)
S24
CALCULATE POSITION DEVIATION OFFSET AMOUNT
Eoffset = K × Fout
K: CONVERSION COEFFICIENT FOR CONVERTING TORQUE COMMAND DEVIATION TO POSITION DEVIATION OFFSET AMOUNT
S25
LIMIT THE POSITION DEVIATION OFFSET AMOUNT
LIMIT SO THAT THE CORRECTION DOES NOT BECOME EXCESSIVELY LARGE
S26
ADD THE POSITION DEVIATION OFFSET AMOUNT TO POSITION DEVIATION AMOUNT
Er = Er + Eoffset
S27
CALCULATE VELOCITY COMMAND
VCMD = Kp × Er
Kp : POSITION GAIN
VCMD:VELOCITY COMMAND

FIG.17

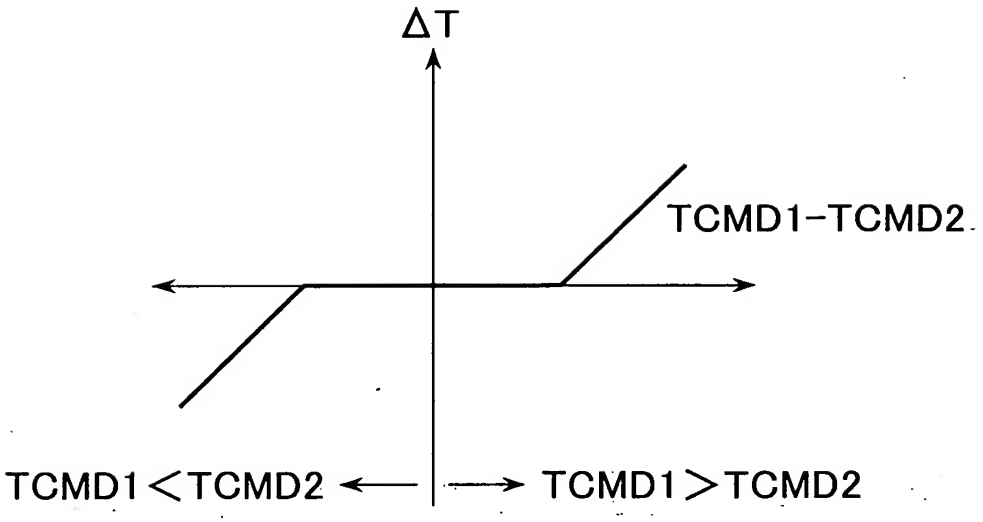

ΔT
TCMD1−TCMD2
TCMD1＜TCMD2
TCMD1＞TCMD2

FIG.18

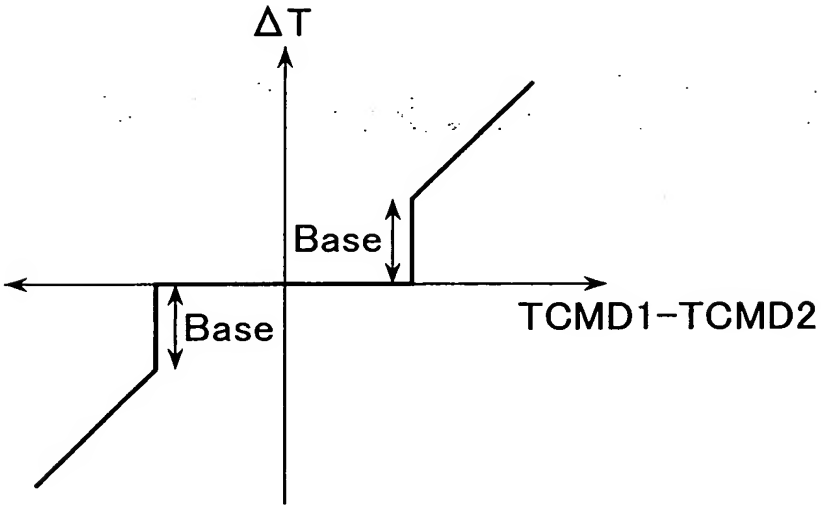

ΔT
Base
Base
TCMD1−TCMD2

FIG.19

ADDING THE POSITION COMMAND OFFSET TO THE POSITION COMMAND

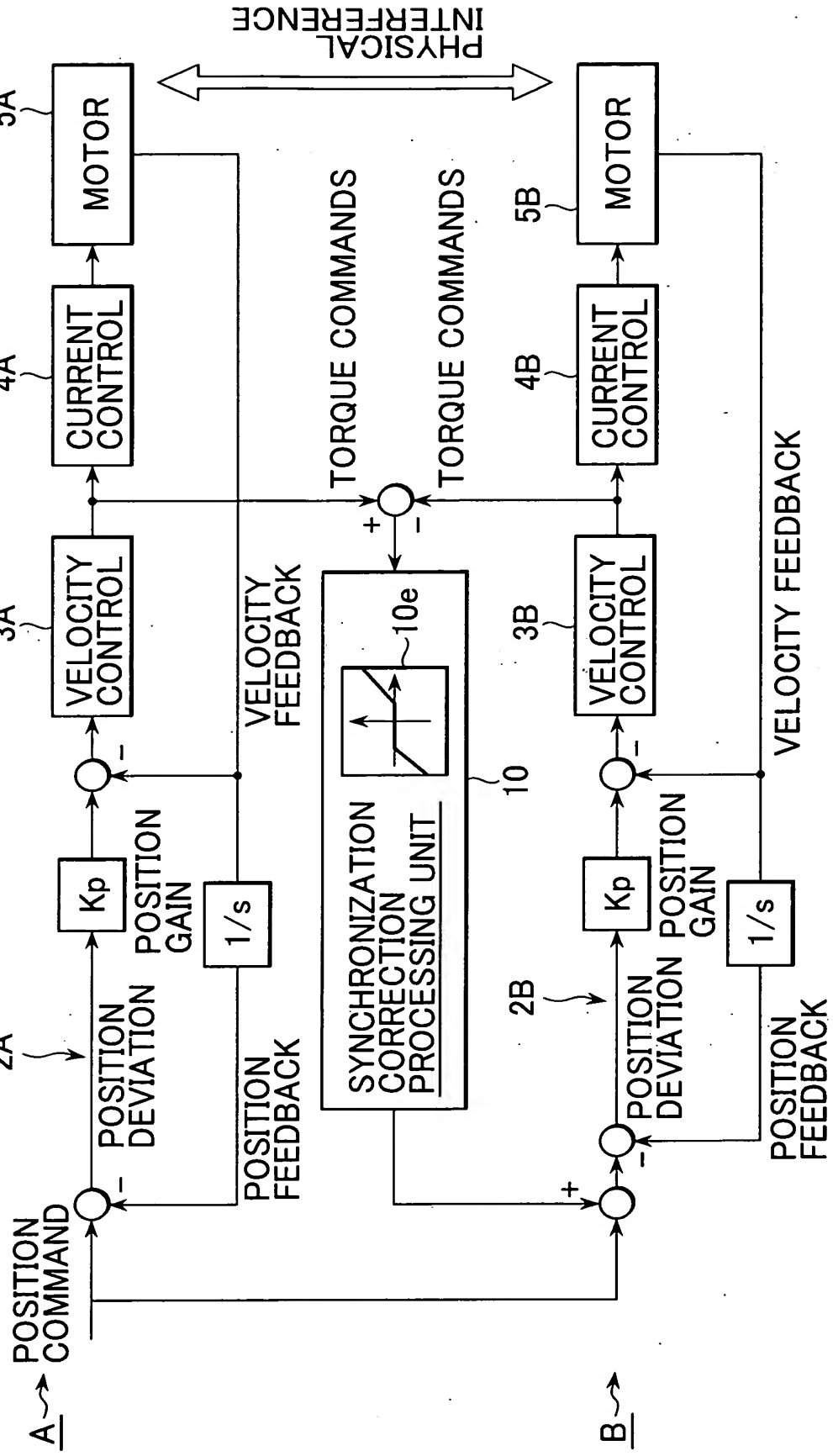
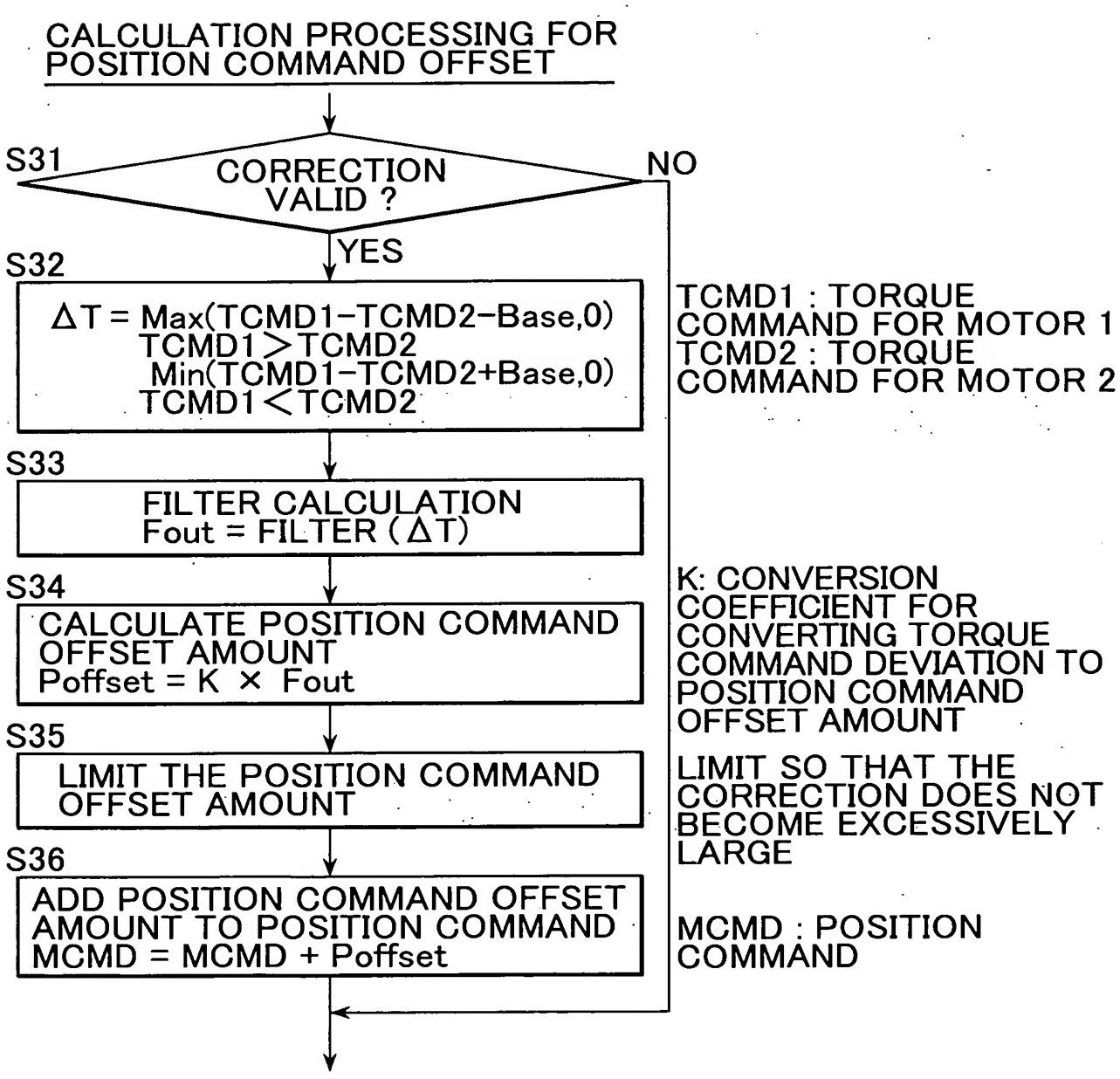


FIG.20


CALCULATION PROCESSING FOR POSITION COMMAND OFFSET
S31
CORRECTION VALID ?
NO
YES
S32
ΔT = Max(TCMD1−TCMD2−Base,0) TCMD1＞TCMD2
Min(TCMD1−TCMD2+Base,0) TCMD1＜TCMD2
TCMD1 : TORQUE COMMAND FOR MOTOR 1
TCMD2 : TORQUE COMMAND FOR MOTOR 2
S33
FILTER CALCULATION
Fout = FILTER (ΔT)
S34
CALCULATE POSITION COMMAND OFFSET AMOUNT
Poffset = K × Fout
K: CONVERSION COEFFICIENT FOR CONVERTING TORQUE COMMAND DEVIATION TO POSITION COMMAND OFFSET AMOUNT
S35
LIMIT THE POSITION COMMAND OFFSET AMOUNT
LIMIT SO THAT THE CORRECTION DOES NOT BECOME EXCESSIVELY LARGE
S36
ADD POSITION COMMAND OFFSET AMOUNT TO POSITION COMMAND
MCMD = MCMD + Poffset
MCMD : POSITION COMMAND